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Section: Original Investigation

Article Title: Pacing Behaviour of Elite Youth Athletes: Analysing 1500-m Short-Track Speed Skating

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"Pacing Behaviour of Elite Youth Athletes: Analysing 1500-m Short-Track Speed Skating"
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Abstract

Purpose: To gain insight into the development of pacing behaviour of youth athletes in 1500-m short-track speed skating competition. **Methods***:* Lap times and positioning of elite short-track skaters during the seasons 2011/2012 - 2015/2016 were analysed (n=9715). The participants were grouped into age groups; under 17 (U17), under 19 (U19), under 21 (U21) and senior. The difference between age groups, the difference between the sexes and the stages of competition within each age group were analysed through a MANOVA ($p<0.05$) of the relative section times (lap time as a percentage of total race time) per lap and by analysing Kendall's tau-b correlations between intermediate positioning and final ranking. **Results***:* The velocity distribution over the race differed between all age groups, explicitly during the first four laps (U17: 7.68±0.80%, U19: 7.77±0.81%, U21: 7.82±0.81%, senior: 7.80±0.82%) and laps 12, 13 and 14 (U17: 6.92±0.14%, U19: 6.83±0.13%, U21: 6.79±0.14%, senior: 6.69±0.12%). In all age groups, a difference in velocity distribution was found between the sexes and between finalists and non-finalists. Positioning data demonstrated that youth skaters showed a higher correlation between intermediate position and final ranking in the laps 10, 11 and 12 compared to seniors. **Conclusions***:* Youth skaters displayed less conservative pacing behaviour compared to seniors. The pacing behaviour of youths, expressed in relative section times and positioning, changed throughout adolescence and came to resemble that of seniors. Pacing behaviour and adequately responding to environmental cues in competition could therefore be seen as a self-regulatory skill that is under development throughout adolescence.

Key words: pacing strategy, head-to-head competition, performance analysis, adolescence, self-regulation.

1. Introduction

The distribution of energy over a race (i.e. pacing) has proven to be a decisive factor in athlete performance in both time trials[1,2] and head-to-head competitions[3-5]. Several modelling and experimental studies have found that there is a multitude of factors that influence the pacing process, which include: the duration of the event[6], perceived level of fatigue throughout the race[7], previously fatiguing exercise (qualification before a final)[8], the competitive environment[5,8], and specific demands of a sport[9]. The outcome of the goal-directed decision-making process involved in pacing is expressed as pacing behaviour[10,11].

In this context, it is known that previous experience plays a crucial role in the development of adequate pacing behaviour[10,12-17]. In fact, pacing has recently been argued to be a self-regulatory learning skill[13]. As a result, the physical changes[18] as well as cognitive changes[19,20] that athletes experience during adolescence, can be expected to have an effect on the development of pacing behaviour of youth athletes[13]. To achieve a better understanding of the goal-directed decision-making process involved in pacing, the development process of this pacing behaviour throughout adolescence should be studied. Surprisingly however, the research into pacing behaviour in youth athletes, both children and adolescents, is scarce[13-15]. The only longitudinal research on the development of pacing strategies in talented adolescent exercisers was a recent study on the development of pacing behaviour of adolescent long-track speed skaters performing a 1500-m race. This study concluded that as youth athletes go through adolescence, their pacing behaviour develops more towards that of senior performers[21]. The more successful long-track speed skaters differentiated themselves by an early adaptation of the lap time pattern similar to that of elite long-track speed skaters[21]. However, this study is performed in a time-trial type sport in which the winner of the event is the speed skater with the fastest completion time[5,22]. Long-track and short-track speed skating are, besides minor physiological differences, rather similar sport disciplines[23]. However, where long-track speed skating is a typical time-trial sport, short-track speed skating features head-to-head races in a highly interactive competitive environment with up to nine athletes in one race[4,24]. With the presence of (multiple) opponents, an additional factor need to be incorporated in the goal-directed decision-making process, related to avoiding collisions, drafting, motivation and the behaviour and expectations of opponents[4,24]. Therefore, to perform successfully, exercisers will need to balance the optimal energetic distribution while taking into account the cues supplied by the environment[8]. Previous research into pacing behaviour in short-track speed skating has focussed on elite senior skaters[4,24]. It was found that elite short-track speed skaters performing a 1000-m and 1500-m race tend to save energy in the initial phase by adjusting their pacing behaviour to that of other competitors[8,24,25]. The saved energy is later used in an 'end-spurt' to position the skater in the foremost position in the final phase of the race, increasing their chances of winning[4]. The saving of energy for an end-spurt at the final stages of the race has been shown to be an effective mechanism to increase performance in a variety of sports disciplines[4,26]. As recent research emphasised the importance of environmental cues in the development and execution of pacing behaviour[5,10], it would be interesting to study pacing behaviour of youth athletes in a head-to-head competition type sport, involving direct competition against multiple opponents where relative rankings are the main determinant for winning.

The aim of the present study was to answer the question: Is there a difference in pacing behavior between elite athletes of different ages in the head-to-head type sport short-track speed skating? Information on the pacing behaviour of elite youth and senior speed skaters, performing in 1500-m short-track speed skating competitions, was gathered and analysed. To achieve a better understanding of the pacing behaviour of speed skaters, two types of analysis were used. First, the intermediate lap times and finishing times of races were examined to analyse the velocity distribution over a race. Secondly, the positioning of the skaters throughout the race was explored. The positioning of the athlete offers different possibilities during the race (e.g. drafting, overtaking and motivational influence), these possibilities influence the decision making process involved in pacing throughout the race. In line with the previous study into pacing behaviour of adolescent long-track speed skating athletes [21], it is hypothesized that the pacing behaviour of younger skaters will deviate from that of elite skaters in key moments such as the start and finish of the race. Additionally, it is hypothesized that with age, the pacing behaviour will come to resemble that of elite senior short-track speed skaters. Previous research revealed that pacing behaviour is influenced by the stage of competition[27] and gender[28]. In order to provide a complete insight into the pacing behaviour of youth skaters, the pacing behaviour of the different sexes and stages of competition will be analysed.

2. Methods

2.1. Participants and events

To analyse the pacing behaviour of youth short-track skaters, an observational research design was used. Finishing and lap times as well as starting, intermediate and finishing positions were gathered of 1500-m races (13.5 laps of 111.12m) performed during Short-track Skating World Cups, the European Championships, World Championships and World Junior Short-track Speed Skating Championships during the seasons 2010/2011 until 2015/16. Each competitive event consisted of qualification stages in which athletes could directly qualify for the next stage by finishing in either first or second place. Additionally, participants could qualify for the next stage indirectly by setting the fastest time in the competition round or through advance by jury decision. Recordings of lap and final times were done electronically with an accuracy of at least one hundredth of a second, as is demanded by the International Skating Union. Position of the participants was coded 1 (participant in first position) up to 9 (participant in ninth position). As the data were publicly available at the International Skating

Union website (http://www.sportresult.com/federations/ISU/ShortTrack/) no written consent was given by the participants. The study was approved by the local ethical committee and is in accordance with the Declaration of Helsinki.

A total of 14783 skating performances (spanning 2197 races) were analysed. Falls and/or disqualifications could affect the lap times and positioning of the athletes and of other competitors, which could lead to a misinterpretation of the results. Therefore, skating performances with falls, disqualifications or missing data were excluded from analysis. Additionally, outliers, defined as lap times that exceeded the mean ± two times the standard deviation, were excluded. After these exclusions, 9715 performances of 1500-m races (65.71%) were included.

2.2. Statistical analyses

Lap times. To compare pacing behaviour independent of skating performance, the intermediate lap times were converted into relative section times (RST) by expressing the lap time as a percentage of the total race time. A difference in RST is therefore a difference in the distribution of velocity, indicating a difference in pacing behaviour, not absolute velocity, which would indicate a difference in performance. The method of normalizing lap times to study pacing behaviour is common practice in pacing studies[21,29]. The participants were categorized in age groups based on the skater’s year of birth and the year in which the analysed race was performed. Participants younger than 17 were placed in the group under 17 (U17), participants who were 17 and 18 years old were placed in group under 19 (U19), participants who were 19 or 20 years old were placed in group under 21 (U21), participants who were older than 20 were placed in group senior. The races were divided by stage of competition, categorizing them as either finals (finals, semi-finals, and quarter-finals) or non-finals (preliminaries, heats, repeated heats and repeated semi-finals). A MANOVA analysis ($p<0.05$)

was used to search for a difference in the distribution of velocity between the age groups, sexes and stages of competition. The RST of the 14 laps were used as the dependent variables and age group (U17, U19, U21 and senior), sex (male, female) and stage of competition (final, non-final) were used as independent variables. A significant difference ($p<0.05$) between the age groups pointed to a difference in the distribution of velocity between age groups. If a significant difference was found, a Bonferroni post hoc analyses would identify in which specific laps of the race the difference in velocity distribution between age groups presented itself.

An significant ($p<0.05$) interaction effect between age group and sex or age groups and stage of competition indicated a difference between the sexes or the stages of competition within an individual age groups. For example: a difference in velocity distribution between males and females within the under 17 age group. If a significant interaction effect was found, an additional MANOVA, which used the RST data of an individual age group as depended variable and sex (male, female) or stage of competition (final, non-final) as independent variable, was performed to explore in which specific lap there was a difference between the sexes or the stages of competition within each individual age group.

2.3. Positioning.

To examine the positioning behaviour of the skaters during the race, the relation between start/intermediate rankings and final-rankings was analysed using Kendall's Tau-b correlations. Positive correlations would indicate that relatively, a top/bottom-place skater in that particular lap was also ranked in top/bottom-place at the end of the race. In contrast, negative correlations would indicate a top-place skater in that particular intermediate lap is related with a bottom-place ranking at the end of the race and vice versa. Through this analyses it is possible to examine the changes in positioning that influence the final outcome of the race. The positioning data of the different age groups were compared as well as the data of all individual age groups divided by sex and stage of competition. Positive and negative correlations were perceived as not present/low ($r < 0.50$), moderate ($0.50 \leq r < 0.70$), or high ($r \geq 0.70$)[4,24].

3. Results

3.1. RST analyses.

Analysing the RST data revealed a significant effect for age group (F_{42}=10.43, p< 0.001), which indicates a significant difference in pacing behaviour between the different age groups. The mean (SD) of the RST and the outcome of the post hoc analyses, indicating the differences in velocity distribution between age groups, are presented in Figure 1. Younger skaters display a lower RST in the initial four laps (mean RST over laps one, two, three and four for age groups U17: 7.68±0.80%, U19: 7.77±0.81%, U21: 7.82±0.81%, and senior: 7.80±0.82%). On the other hand, the younger skaters display a higher RST in the final three laps (mean RST over laps 12, 13 and 14 for age groups U17: 6.92±0.14%, U19: 6.83±0.13%, U21: 6.79±0.14%, and senior: 6.69±0.12%).

A significant interaction effect was found for age group and sex (F_{42} = 2.978, p < 0.001), indicating a difference between the sexes in different age groups. The mean (SD) of the RST of male and female participants in the individual age groups were presented in figures 2. The additional MANOVAs revealed a significant difference in the distribution of velocity between the sexes in age groups U17 (F_{13} = 2.372, p = 0.006), U19 (F_{14} = 2.331, p = 0.004), U21 (F_{14} = 4.045, p < 0.001) and senior (F_{14} = 27.258, p < 0.001). The laps wherein a significant difference between sexes was found are indicated in figure 2.

Furthermore, a significant interaction effect for age group and stage of competition was found (F_{42} = 3.917, p = 0,000), indicating a difference in pacing behaviour between the finals and non-finals in different age groups. The mean (SD) of the RST of finalists and non-finalists in each age group as presented in figure 3. The additional MANOVAs presented a significant difference in the distribution of velocity between the finalists and non-finalists in age groups U17 ($F_{13} = 2.654$, $p = 0.002$), U19 ($F_{14} = 10.027$, $p < 0.001$), U21 ($F_{14} = 10.293$, $p < 0.001$) and senior ($F_{14} = 36.217$, $p < 0.001$). The specific laps in which a difference between finalists and non-finalists was found are indicated in figures 3.

3.2. Position analyses.

The Kendall's Tau-b correlations between intermediate positioning and final ranking of the age groups are presented in Figure 4. The positional data for the individual age groups and categorized by sex, are presented in Figure 5. The positional data for the individual age groups and categorized by stage of competition, are presented in Figure 6.

4. Discussion

The main aim of the current study was to explore differences in pacing behavior between elite speed skating athletes of different ages. It appeared that younger skaters demonstrated a relatively fast start compared to senior skaters. Vice versa, the senior skaters displayed a more conservative pacing which included a relatively slow start and fast finish, compared to younger skaters. The positioning data pointed out that younger skaters display a higher correlation between positioning in the intermediate laps and final ranking earlier on in the race, in comparison to seniors. These findings support the hypothesis that the pacing behaviour of youth short-track skaters deviates from that of senior skaters in key moments of the race. The largest differences in the RST data exist between the youngest and senior age groups and these differences seem to become smaller with age, suggesting that the pacing behaviour of youth skaters changes towards that of senior skaters, throughout adolescence. Comparable to the RST data, the positional data presented a similar trend which suggests the pacing behaviour of youth athletes changes throughout adolescence to resemble that of senior athletes. These findings support the current study’s hypothesis and match the outcome of previous research regarding the development of pacing behaviour in adolescent long-track skaters[21]. In this respect, it seems that pacing behaviour can indeed be seen as a self-regulatory skill is under development throughout adolescence.

A possible explanation for the difference in both the RST and positional data between younger and older skaters could be linked to experience. Previous research pointed out the importance of experience in the development of the pacing skillset[12,14,15,21]. As seen in previous research, the development of the skill to anticipate future physiological requirements is important in successful pacing[14,16,17]. During the final phase of the race, lap times decrease and the level of fatigue increases[4]. Therefore, during the last phase of the race, skaters need to interact in a highly interactive competitive environment under fatiguing conditions. Older skaters possess more racing experience, and therefore could have a more developed anticipatory skillset. The higher level of experience in senior skaters is apparent as their pacing behaviour is more conservative, therefore preserving energy for the final moments of the race[4]. An argument could be made that following the pace of an opponent can be more physiologically demanding[26]. Adopting a pacing strategy aimed at completing the event as fast as possible, without adopting a similar pace as competitors, could accordingly potentially increase the chances of winning by lowering physiological demands. This would entail that taking leading positions early in the race could be considered more optimal. However, previous research in elite senior short-track skaters has shown that this strategy is not associated with better performances[25].

The results of the current study support the idea that athletes develop the underlying physical and cognitive functions needed for functioning pacing skills throughout adolescence[13,21]. It is suggested that through the gathering of experiences in training and competition as well as evaluating previous races, athletes learn to more accurately plan their race and respond to environmental stimuli[13]. Where previous research focused primarily on the planning strategy and the reaction to internal cues such as muscle fatigue[12,16,17,30], the demonstrated development of pacing behaviour as well as positioning strategies with age in a highly interactive, head-to-head sport such as short-track speed skating in the present study makes a case for an additional emphasis on the influence of environmental cues in addition to the internal cues as suggested previously[5,10,13].

Comparing the pacing behaviour between different sexes revealed a change in pacing behaviour with age. The RST data revealed that the female youth skaters tended to demonstrate a relatively slow start of the race, compared to their male counterparts. Especially in the youngest age group, female skaters seemed to start slower and finish faster compared to male skaters. The conservative start and high performance finish is similar to the behaviour seen in older age groups. It could be stated that the pacing behaviour of youth female skaters is more similar to that of older age groups, compared to the male skaters in the same age group. Additionally, the positioning data revealed that the positing behaviour of female skaters in the U17 age group resembled that of older age groups far more compared to the male skaters in the same age group. A possible explanation for the difference in pacing behaviour could be the difference in onset of puberty, and the associated changes in physical and cognitive functioning, between sexes[31,32]. As seen in previous research, pacing is dependent on several facets of cognitive functions including the anticipation of future physiological requirements, deductive reasoning, understanding of the self-physiology and deductive reasoning[14,17,33]. As females reach puberty several years earlier compared to males, the physical and cognitive functioning which influences pacing behaviour might be further developed, resulting in a pacing behaviour which shares more resemblance with older athletes[13]. Earlier research in adolescent track and field athletes seems support this notion as it was suggested that female athletes pace their performance more conservatively in comparison to male athletes[28].

Comparing the pacing behaviour between the different stages of competition revealed a similar pattern across all age groups. The analyses of RST data revealed that the pacing behaviour of skaters in finals is more negatively orientated including a more conservative start with a high RST percentage and a finish with a lower RST percentage, compared to non-finals. Moreover, the positioning data indicate that the correlation between the position of a skater during an intermediate lap and the final ranking of the skater is higher in an earlier stage of the race in non-finals. Which would suggest that during finals the final ranking is determined by actions made in the final laps. These finding are conform with earlier research in elite senior athletes[4].

5. Practical applications

It was previously put forward that the pacing behaviour of talented adolescent long-track speed skaters seems to be an indicator of their performance in a later point of their career[21] indicating the value of pacing behaviour in talent development and selection. The current study emphasizes the importance of both experience and environmental cues in pacing behaviour in short-track speed skating extending the claim that the development and implementation of the pacing skillset is not only important in time-trial sports but also in head-to-head competition sports[5,10,13]. It would therefore be of value to analyse and train pacing behaviour of young athletes who are engaged in head-to-head competition, in order to guide the development of pacing behaviour in the most beneficial direction. It is suggested that the process of self-regulation could be a beneficial factor to the development of pacing behaviour[13]. The employment of training sessions that sharpen self-regularity skills through reflection, planning, monitoring, adapting and evaluation could positively influence the pacing development process[13]. The specific findings for age groups, sex and stage of competition in the current research could be used as a benchmark in the implementation of self-regulatory skill based model.

6. Conclusions

The current research is the first to analyse the pacing behaviour of youth athletes of different ages performing in head-to-head competition. We have taken a rigorous approach and analysed almost 10,000 races, lap times as well as positional data, of youth athletes and found that their pacing strategies and positioning developed throughout adolescence towards the less conservative profiles seen in senior elite athletes. These findings stress the importance of experience, physical and (meta)cognitive development, and understanding of one's own physiology in the development of the pacing skill, and suggest that pacing behaviour can indeed be seen as a self-regulatory skill that can be learned. Additionally, the occurrence of the development of pacing behaviour in a head-to-head type competition further emphasises the importance of environmental cues: pacing and adequately responding to environmental cues in competition is a self-regulatory skill that is under development throughout adolescence. Results are relevant in order to be able to optimally guide youth athletes in terms of their pacing strategies, and will have impact on coaching practice. Talent development programs of head-to-head sports could benefit by increasing the focus on pacing behaviour development during adolescence.

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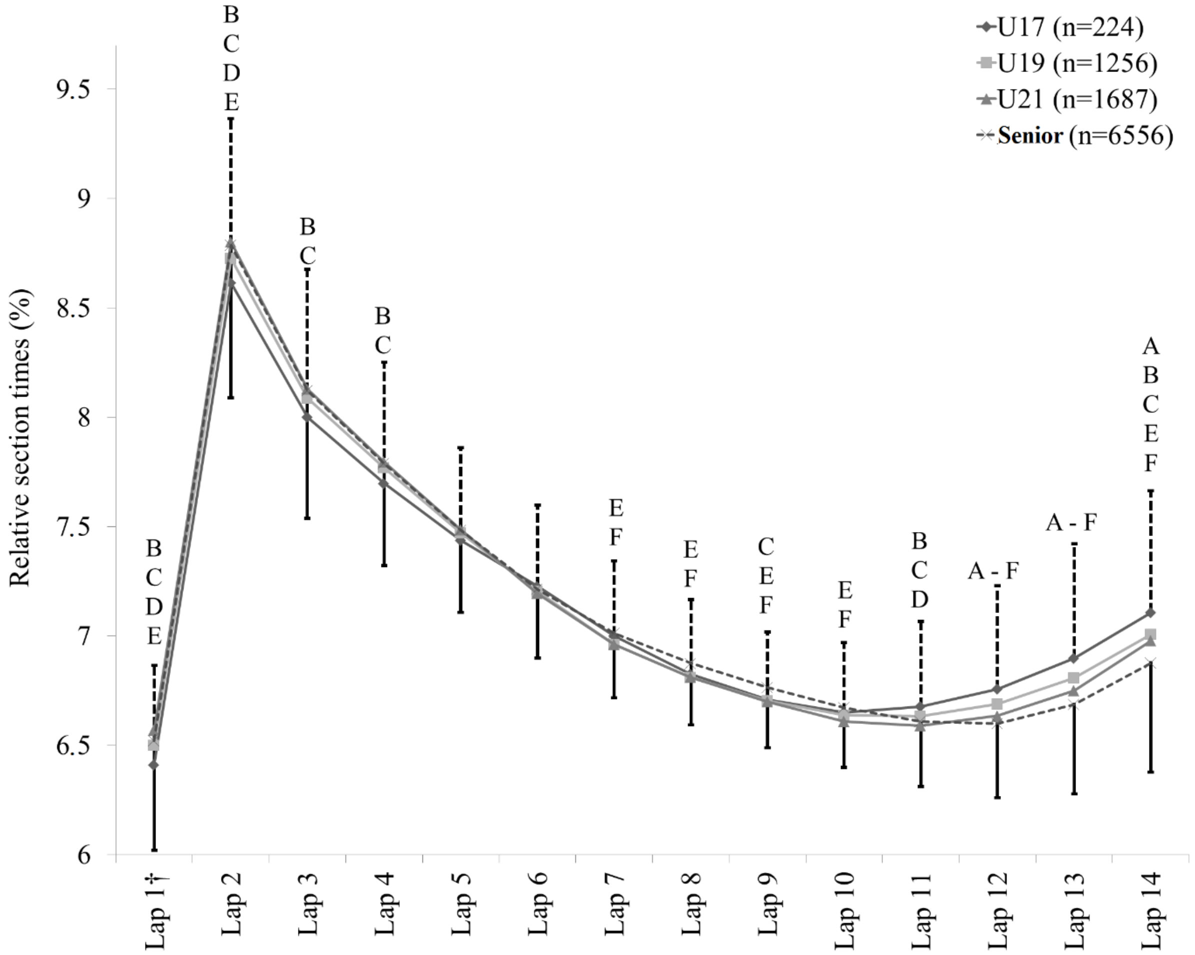

† = Lap 1 accounts for only the first ½ lap
A significant difference (p<0.05) in RST between: [A]U17 and U19, [B]U17 and U21, [C]U17 and Adult, [D]U19 and U21, [E]U19 and Adult, [F]U21 and Adult.

Figure 1. Relative section times of individual laps for each age group.

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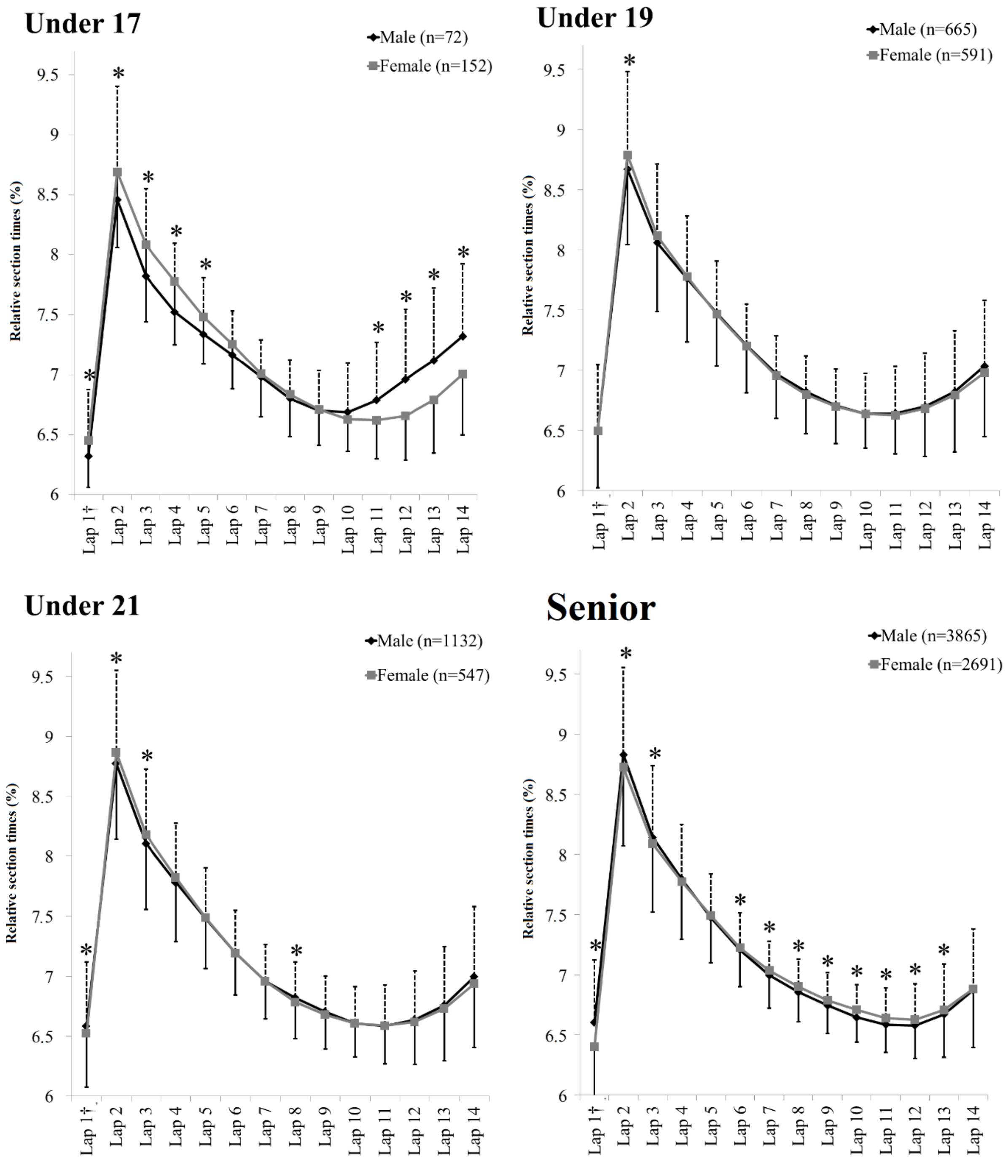

* = significant difference ($p < 0.05$)
† = Lap 1 accounts for only the first ½ lap

Figure 2. Relative section times (%) of individual laps for males and females in each particular age group.

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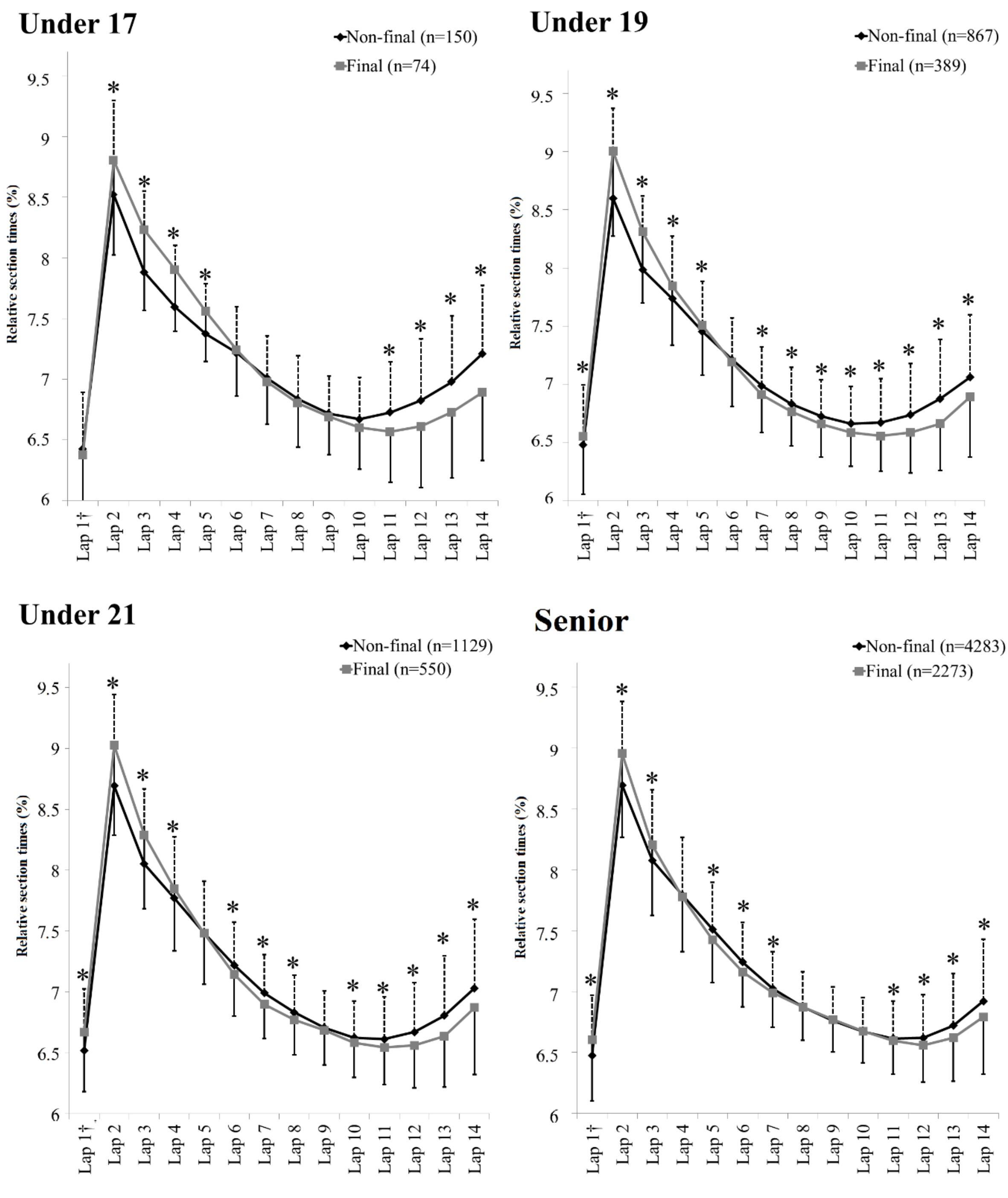

* = significant difference (p < 0.05)
† = Lap 1 accounts for only the first ½ lap

Figure 3. Relative section times (%) of individual laps for performances in finals and non-finales in each the particular age group.

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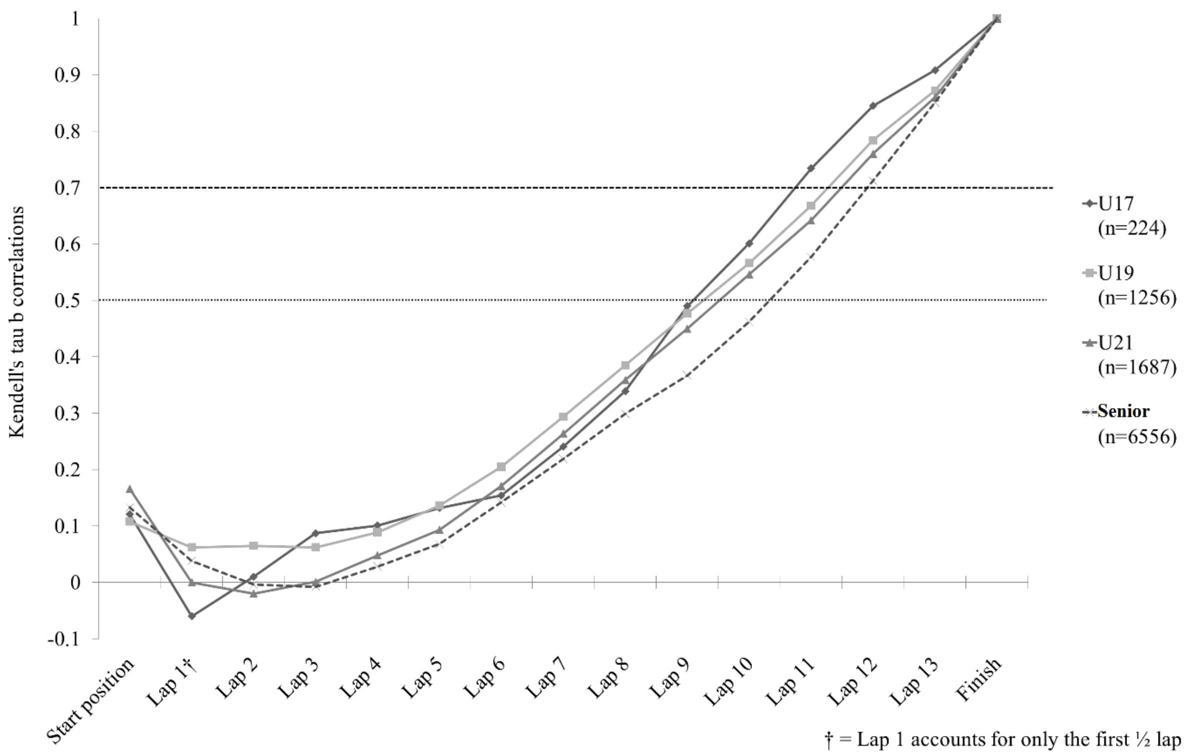

Figure 4. Kendell’s tau b correlation between intermediate and final ranking during individual laps for each age group.

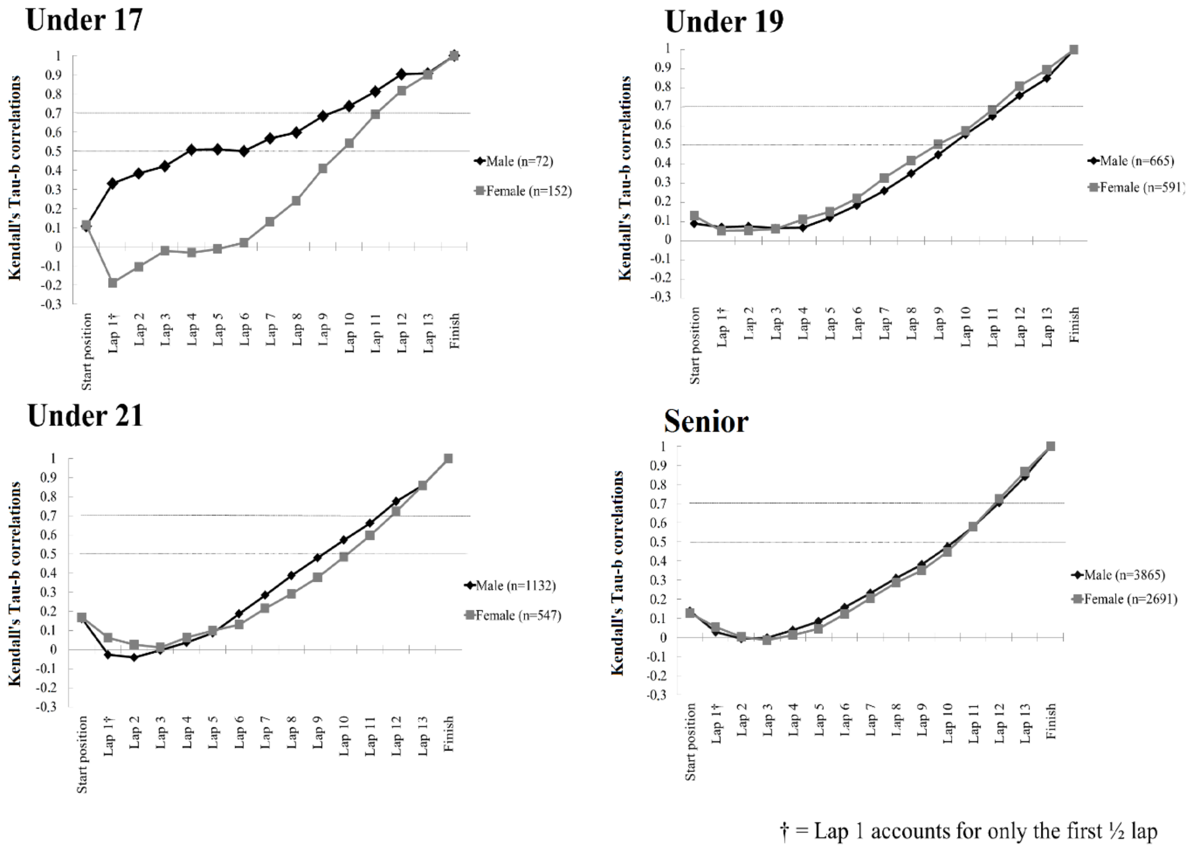

Figure 5. Kendell’s tau b correlations between intermediate and final ranking during individual laps for males and females in each particular age group.

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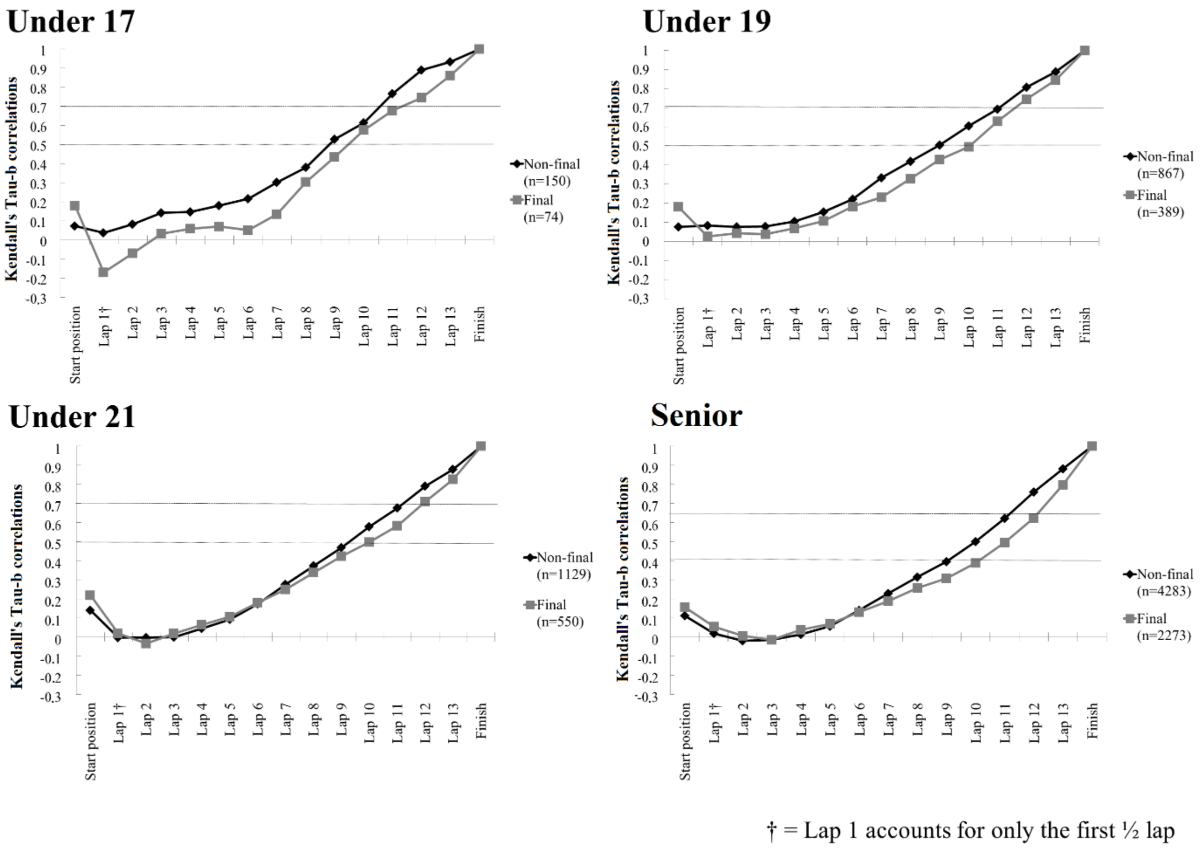

Figure 6. Kendell's tau b correlations between intermediate and final ranking during individual laps for performances in finals and non-finals in each particular age group.